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Using an empirical traffic light procedure for monitoring and forecasting in the Gulf of St. Lawrence fishery for the snow crab, *Chionoecetes opilio*

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Abstract

A traffic light procedure is used for comparing temporal evolution of indicators of the snow crab (*Chionoectes opilio*) abundance, fishery success and environmental change. Indicators related to recruitment success in the fishery between 1968 and 2003 were followed and comparisons with life history stages (in trawl surveys conducted over 15 years) allowed the temporal sequence of events in the life cycle to be established. Although recruitment seems to be synchronized with bottom temperature, and may be related to abundance changes in groundfish predators, the main factors determining recruitment fluctuations appear to be density-dependent interactions between life history stages. Establishing the abundance and timing of successive life history stages using the traffic light approach seems to provide a reliable indication of their passage through the fishery, and might be used to make forecasts of the condition of the fishery several years ahead. The analysis raises the question of which of a number of possible density-dependent factors are dominant. Two management approaches by reference points and fisheries control rules are suggested.

Keywords: Snow crab; Traffic light; Fisheries management; Indicators

1. Introduction

1.1. Broadening the information basis for fisheries management

Most models commonly applied to fisheries management use time series of information; often combinations of data on catch, its size or age composition, with fishing mortality derived by some variant of cohort analysis. Survey biomass estimates,

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their age structure and the fishing mortality or stock size and recruitment, can be derived from surveys and/or catch sampling. One current pre-occupation in fisheries theory has been how to use a wider range of information sources, which take into account biotic and abiotic environmental information and food web interactions.

Criticisms have been made of the limited number of data series collected for most fisheries; in particular, pre-mature decisions on key factors can be in error. However, once a model-based framework is in place, it will be difficult to change it or use it to test other hypotheses. A strategy, which avoids building in a specific model-based sampling approach, is less likely to incorporate misconceptions into an eventual modeling framework. A broad indicator-based approach to monitoring successive life history stages and their environment offers more opportunity to pick up changes in critical factors over time, such as might be due to regime shifts or changes in ecosystem components. The traffic light system (Caddy, 1999; Koeller et al., 2000; Halliday et al., 2001) offers a framework for comparing data series prior to deciding what critical factors to incorporate into models. It also provides a way of confronting different indicator series, and comparing the relevance of a wide range of informational inputs to the management process, and is well adjusted for understanding by non-technical audiences. We also explore ways of comparing indicators that may differ widely in numerical range and measurement units, by condensing all data series down to segments of the observed range of values in the data series. We also review the evidence for an orderly transition between sequential life history stages of snow crab, *Chionoecetes opilio*, and what this may promise in terms of forecasting fishery success. In the past 20 years, the snow crab fishery has grown tremendously in importance economically in Atlantic Canada and is presently one of the major fisheries with landings valued at over US$700 M in 2000.

1.2. Using color to add information to graphical output

The traffic light displays time series in such a way that synchronous transitions in indicator values over a wide range of characteristics can be appreciated visually. The technique is not a substitute for standard statistical procedures, but the traffic light display helps to perceive likely relationships between variables.

The TL approach was a development of precautionary reference points (Caddy, 1999), such that the 'color boundaries' ideally correspond to limit (lim) or precautionary (pa) RPs in the ICES convention (ICES, 1997); but this is not the TL application aimed at here. A substantial series of biological time series have accumulated in the snow crab research database, but limit reference points (LRPs) have not yet been developed, hence at first color boundary values will have to be decided upon empirically. Our longer term strategy will be to use research results to fine-tune these empirical reference points and incorporate them into a management rule. However, the empirical approach described here allows progress to be made immediately in developing an indicator 'traffic light board', and summarizes multiple indicators into a series of characteristics for the fishery which are easily understandable to managers and stakeholders, and can be used directly in fishery management decisions (Caddy, 2002).

1.3. History of monitoring and research on snow crab stocks in the Gulf of St. Lawrence

Prior to 1988, monitoring of the southern Gulf of Saint Lawrence (sGSL) snow crab fishery was restricted to fishery data and sparse at-sea observer data. During this period, the snow crab fishery was a competitive fishery which was transformed to an individual quota system in 1989. With the exception of 1996, since 1988 a trawl survey dedicated to snow crab related research has been conducted in Area 12 (Fig. 1) after each fishing season. This survey has provided a better perspective on overall population structure, and was needed, since the fishery is a male-only fishery and commercial traps have limited catchability for smaller males or females below the legal size of 95 mm carapace width (CW). Hence, the fishery yields little information on earlier life history stages.

Research has also been conducted on various aspects of the snow crab life cycle in the sGSL, such as growth (Hébert et al., 2002a; Moriyasu et al., 1988; Sainte-Marie et al., 1995), on reproduction (Conan and Comeau, 1986; Elner and Beninger, 1992; Moriyasu and Conan, 1988; Sainte-Marie and Carriére, 1995; Moriyasu and Comeau, 1996) and natural mortality of the commercial portion of the stock (Wade et